AI-Based Model Reduction for Real-Time Predictive Simulationin Solid Mechanics

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Abstract

The rise of machine learning techniques offers new opportunities for model reduction in solid mechanics, particularly for applications requiring real-time predictions. This study presents a hybrid approach that combines classical model reduction techniques, such as Galerkin projection and proper orthogonal decomposition, with deep neural networks to enhance computational efficiency and accuracy.
We introduce a supervised learning architecture designed to extract optimized latent representations of stress and displacement fields from high-fidelity simulations. The use of convolutional neural networks (CNNs) and deep operator networks (DeepONet) significantly accelerates computations by efficiently capturing the underlying dynamics of complex materials and structures.

The performance of our approach is evaluated on benchmark structural mechanics problems, including heterogeneous materials and complex boundary conditions . Our results demonstrate a substantial improvement in computational speed compared to traditional methods while maintaining a high level of accuracy.

This methodology paves the way for the integration of intelligent reduced-order models into embedded systems, interactive simulations, and real-time structural optimization.
Keywords: Model reduction, machine learning, neural networks, solid mechanics, real-time simulation.

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